Modeling and evaluating construction project competencies and their relationship to project performance

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ABSTRACT

In contemporary construction environments, construction organizations measure their performance against a set of predefined performance measures. These performance measures are governed by the ability of the organization to maintain necessary sets of "competencies" that assist in the successful execution of its construction projects. Competencies are often difficult to define and measure due to the multidimensional and subjective nature of their assessment. This paper identifies 41 project competencies with a total of 248 criteria for evaluating the different project competencies. This paper also identifies seven performance categories with 46 project key performance indicators. A systematic framework and methodology are presented in this paper to measure project competencies and project key performance indicators. A new modeling approach considering prioritized fuzzy aggregation, factor analysis, and fuzzy neural networks is presented to identify the relationship between project competencies and project key performance indicators. Data collected from seven construction projects are first aggregated using prioritized fuzzy aggregation to measure the different construction project competencies. The different project competencies are then analyzed using factor analysis. The factor analysis results are used with the prioritized fuzzy aggregation results to calculate inputs for the fuzzy neural networks. The fuzzy neural networks are then trained and tested using the data collected from the seven construction projects to identify and quantify the relationship between the different project competencies and project key performance indicators. This paper contributes to the current body of knowledge in project competencies and performance by establishing a standardized framework and methodology for evaluating the impact of construction project competencies on project key performance indicators. Furthermore, this paper incorporates advanced modeling techniques through the application of fuzzy set theory and neural networks to identify the relationship between the different project competencies and project key performance indicators. Identifying the relationship between construction project competencies and project key performance indicators allows construction organizations to improve their overall construction project performance by enhancing their projects competencies.

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1. Introduction

In today's dynamic construction industry, construction organizations encounter many challenges resulting from the increasing uncertainties in technologies, budgets, and development processes [2]. Hence, construction projects are completed as a result of merging many events and interactions, with varying participants and processes in a constantly changing environment [31]. Many of these events and interactions can be quantified and used to differentiate superior from average performance. Spencer and Spencer [34] described the measurable events and interactions that distinguish different performance levels as "competencies". These competencies are fundamental to evaluate construction organizations and projects in order to achieve better performance on the organizational and project levels [22,33].

Competencies in general are difficult to evaluate due to the multidimensional and subjective nature of their assessment. Previous research has addressed project competencies in construction by describing project competencies, in many situations, as project performance. Additionally, previous research in the areas of project competencies focused mainly on evaluating the different sets of competencies rather than identifying the relationship between project competencies and performance [3,35]. Little research investigated the relationship between project competencies and performance through simple statistical techniques such as correlation and multiple linear regression analysis [15,18].

Identifying the relationship between different project competencies and project key performance indicators (KPIs) will assist in recognizing project competencies that require improvement for better project

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performance. Furthermore, the ability to identify and enhance project competencies that affect project performance is expected to improve the competitiveness and profitability of construction organizations [12].

This paper first summarizes previous research to identify current gaps in the areas of project competencies, project performance, and the relationship between competencies and performance. Then, a detailed breakdown and list of project competencies and project KPIs is presented. Next, a methodology for measuring and evaluating project competencies and project KPIs is provided. Finally, the relationship between project competencies and project KPIs is identified through advanced modeling techniques using prioritized fuzzy aggregation, factor analysis, and fuzzy neural networks. Results, conclusions, and future work pertaining to this paper are presented.

2. Background on construction project competencies, project performance, and their relationship

Spencer and Spencer [34] defined competencies as a combination of motives, traits, self-concepts, attitudes, content knowledge, or cognitive behavior skills that differentiate superior from average performers. Spencer and Spencer [34] concluded that in order to adequately measure performance, the personal and professional competencies of individuals in an organization need to be considered.

Sparrow [33] introduced a competency study that combined the different concepts of competencies in past research and classified them into two main approaches: a management competency approach to measure effectiveness across different sectors, and a behavioral competency approach to measure individual competencies within each sector. Significantly, Sparrow's work segregates the organization as a unit to be analyzed distinct from individual competencies, which it considers another unit.

Walsh and Linton [35] limited their investigation to core organizational competencies, and distinguished between competencies and capabilities. They defined competencies as "firm specific technologies and production related skills", and capabilities as "firm specific business practices, processes and culture" [35]. A competency pyramid of organizational competencies was developed as a result of aggregating the two categories. In this pyramid, technical competencies and managerial capabilities were used as a measure of organizational performance.

Markus et al. [19] defined competencies as a generic body of knowledge, motives, traits, self-images, and social roles and skills that are casually related to superior or effective performance in the job. They identified three approaches for modeling competencies: the educational approach, psychological approach, and business approach. The business approach – wherein inputs to the competency model consist of organizational competencies for competitive advantage, including core competencies, capabilities, and practices – is most relevant to the construction domain; outputs of a business-based competency model are measured in terms of performance indicators, such as communication and interpersonal skills, to assess organizational performance.

Alroomi et al. [3] developed a core-competency framework and methodology for cost estimators in the construction domain. Using a criticality matrix to prioritize, Alroomi et al. [3] used the combined effects of each competency's level of importance of each and its associated gap between its ideal and actual level to measure the different competencies. The factor analysis method was applied to investigate the correlation effects of the different estimating competencies, which resulted in a reduced set of core estimating competency factors representing the core estimating competencies for cost estimators.

Omar and Fayek [22] proposed a framework and methodology for measuring construction project competencies. The framework categorized the different competencies into technical and behavioral competencies. Technical competencies stem from organizations, while behavioral competencies are attained by individuals. Together, the two categories contribute to support performance improvement on construction projects.

In many situations, previous research addressed project competencies as project performance [12]; in conflating these two distinct concepts, such research failed to separately investigate the different performance measures, or to recognize that project competencies are in fact leading indicators of project performance. In order to establish this relationship between project competencies and project performance, project performance measures must be identified.

Using project performance measures enables the assessment of project and organizational performance throughout the project life cycle. In order for performance measures to be effective, the measures or indicators must be accepted, understood, and owned across the construction organization and its different construction projects [5,8,21].

The American chemical company DuPont [4] presented the return on investment (ROI) indicator and the pyramid of financial ratios in the early 20th century. Many of the financial performance methods and techniques developed by DuPont are used today in the construction industry and are implemented on the organizational and project levels. Pinto and Pinto [27] stated that measures for enhanced project performance should also include the satisfaction of different project parties with the project's performance; they referred to such subjective measures as "soft" measures. Kometa et al. [17] used a comprehensive approach to evaluate construction projects performance by defining a set of key performance indicators (KPIs) criteria. The KPIs included: safety, construction cost, running/maintenance cost, time, and flexibility to users.

Recent research has focused on evaluating construction project performance through best practices and benchmarking programs. The construction best practice in UK introduced the KPIs measurement program, where, sets of KPIs are defined for different project and organizational levels that directly reflect the current performance and performance targets for construction organizations and projects [11]. Similarly, the Canadian Construction Innovation Council (CCIC), the Construction Industry Institute (CII) and the Construction Owners Association of Alberta (COAA) have each developed a benchmarking program that facilitates data collection and producing results pertaining to performance measurement [6,7,20,28].

As discussed earlier, little research has been previously conducted to identify the relationship between project competencies and project performance measures. Levenson et al. [18] applied descriptive statistics, factor analysis, and correlation and regression analyses to identify the relationships between managerial competencies and then between managerial competencies and performance. First, correlation analysis was performed to measure the correlation relationships between the different managerial competencies. Then, factor analysis was performed to group the different competencies in order to conduct a regression analysis. Finally, regression analysis was performed to identify the relationship between the grouped competencies (i.e., from factor analysis) and performance.

Isik et al. [15] applied a structural equation modeling analysis to establish the relationship between the different management competencies and organizational strengths/weakness as a performance measure. A relationship between the different management competencies and corporate strengths/weakness was identified as a result of applying structural equation modeling.

Because it often considered project competencies as a measure of project performance [12], previous research did not investigate project competencies as a prerequisite for project performance, nor did it consider the fact that project competencies are leading indicators for measuring project performance improvement. A comprehensive framework and methodology for evaluating project competencies and identifying their relationship to project performance has not yet been comprehensively explored. This paper presents a detailed framework and methodology to evaluate project competencies and project KPIs. This paper also applies fuzzy set theory and neural networks (i.e., fuzzy neural networks) to establish and identify the relationship between project competencies and project KPIs.